First and repeated records of the tropical-temperate crab Asthenognathus atlanticus Monod, 1932 (Decapoda: Brachyura) in the eastern part of the Bay of Seine (eastern English Channel, France)

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First and repeated records of the tropical-temperate crab *Asthenognathus atlanticus* Monod, 1932 (Decapoda: Brachyura) in the eastern part of the Bay of Seine (eastern English Channel, France)

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Condensed title: *Asthenognathus atlanticus* in the Bay of Seine

Abstract: *Asthenognathus atlanticus* Monod, 1932, has been reported for the first time from the eastern part of the Bay of Seine (eastern English Channel). A total of 30 specimens were collected between the years 2008 and 2011, along the Normandy coast from Ouistreham to Antifer, mainly on mud and muddy sand habitats, between 10m and 25m depth. The distribution range of *A. atlanticus* has been previously known to cover eastern Atlantic coasts from Angola to the western English Channel, where it reached its northern limits. It is also present in the western part of the Mediterranean Sea. The changes in the sediment composition of the eastern Bay of Seine have probably led to the development of a potentially favorable habitat for this species. However, the data collected have not yet been sufficient to ascertain the origin, and the method of introduction of the eastern English Channel specimens. In the discussion, we ponder if they might have originated from the western English Channel populations, and was transported as larvae in the eastern English Channel; they could have originated from a more distant population, and have been brought to the eastern English Channel through human activities. Each hypothesis is possible in theory.

Résumé : La présence d'*Asthenognathus atlanticus* Monod, 1932, est signalée pour la première fois dans la partie orientale de la baie de Seine (Manche orientale). Un total de 30 individus a été échantillonné entre 2008 et 2011 le long des côtes normandes entre Ouistreham et Antifer, principalement sur des vases plus ou moins sableuses, entre 10 et 25 m de profondeur. L'aire de répartition géographique d'*A. atlanticus* s'étendait auparavant le long des côtes Est de l'océan Atlantique, de l'Angola jusqu'à la partie occidentale de la Manche qui constituait la limite septentrionale de cette espèce. Ce crabe était également signalé dans la partie occidentale de la Méditerranée. Les modifications récentes de la composition sédimentaire des fonds de la baie de Seine orientale ont conduit à la mise en place d'habitats potentiellement favorables pour cette espèce. Cependant, les informations disponibles ne sont

pas suffisantes pour établir de manière définitive l'origine des individus récoltés, ni les modalités de leur arrivée en Manche orientale. Plusieurs hypothèses sont évoquées : d'une part une colonisation naturelle par la dispersion de larves originaires des populations de la Manche occidentale et d'autre part, la possibilité d'une origine plus lointaine, l'introduction des individus collectés étant alors liée aux activités humaines. En l'état actuel des connaissances, aucune hypothèse n'est à exclure.

Key Words: Crustacea Decapoda; *Asthenognathus atlanticus*; Bay of Seine; geographical extension; eastern English Channel.

Introduction

Asthenognathus atlanticus Monod, 1932, is a small (~10 mm), tropical-temperate brachyuran crab (Udekem d'Acoz, 1999) belonging to the family Varunidae (Ng *et al.*, 2008). This species, mainly living in muddy sediment habitats, is often described as being commensal with tubicolous organisms such as the anthozoan, *Cerianthus membranaceus* Spallanzani, 1784, the synaptid echinoderm, *Labidoplax digitata* Montagu, 1815, the sipunculid, *Sipunculus nudus* Linnaeus, 1766 or the terebellid polychaete *Neoamphitrite edwardsi* Quatrefages, 1865 (Glémarec & Hily, 1979).

Previously, this inconspicuous species was known to be an eastern Atlantic species, present from northern Brittany in the Bay of Morlaix to the African coast south of Angola (Udekem d'Acoz, 1999). It also lives in the Western Mediterranean Sea off Banyuls sur Mer (France) (Noël & Amouroux, 1977), as well as along the Algerian coasts (Glémarec & Hily, 1979). Although the first description of this species, based on Moroccan individuals, only occurred in 1932 (see Monod, 1932), it was known to be present in the western English Channel, around Roscoff, since 1921 (Pérez, 1942; Bocquet, 1963; Bourdon, 1965) but remained rare in this northern Brittany location. Thus, during the long-term survey of the 'Rivière de Morlaix' station (10 m depth) in the Bay of Morlaix (Dauvin, 1982, 2000), only three specimens of *A. atlanticus* were collected: one specimen in February 1980, one specimen in April 1981 and the last specimen in December 1995.

The presence of this species has also been reported in Cornwall (Costello *et al.*, 2008), but there is no more detailed publication about this observation after. It is consistent with the fact that *A. atlanticus* larvae had been reported in the United Kingdom waters including Scotland (Pan & Hay, 2010). However, Pan & Hay (2010) also indicated that no adult specimen has been sampled around the British Isles. Hayward & Ryland (1990) reported that

the species was probably present around the Channel Islands, but this has never been confirmed. However, the species has been observed in a sea-grass meadow off Saint-Malo in 2008 (48°38.96'N 02°02.04'W; Grall, pers. observ.). In the eastern part of the English Channel and the Bay of Seine, this crab has never been observed before December 2008 despite numerous studies that have been implemented since 1970s (Gentil & Cabioch, 1997; Thiébaut *et al*., 1997; Ghertsos, 2002; Barnay, 2003; Dauvin *et al*., 2004; Dauvin *et al*., 2007).

Materials and methods

The observations of *A. atlanticus* have been reported in several studies and monitoring programs (Dancie *et al.*, 2010; Laurand *et al.*, 2010; Alizier, 2011; Dancie, 2011; Lanshere *et al*., 2011). The eastern part of the Bay of Seine is actually the location of many facilities and amenities likely to affect coastal and estuarine environments. This is mainly due to the presence of three ports of international importance: Port of Le Havre, the crude oil terminal in Le Havre-Antifer and the Port of Rouen.

Since 1986, the macrofauna distribution in the eastern Bay of Seine has regularly been studied during the winter benthic surveys, especially the PECTOW (PECtinaria OWenia campaign) surveys, organized before the recruitment period of the dominant species, have occurred in 1986, 1987, 1988, 1991, 1996, 2001, 2006 and 2011 (Thiébaut *et al*., 1997; Barnay, 2003; Dauvin *et al*., 2007; unpublished data). Up today, data from a total of eight campaigns, with a grid of 40 to 77 stations according to the year, are available. These winter samples were collected using a Hamon grab (0.25 m², about 15 cm depth) with two benthic macrofauna replicates at each station.

In addition, over the last ten years, new amenities and projects have increased the need for benthic monitoring: i) Port 2000, or the extension of the Port of Le Havre, ii) the project to implant a Liquid Natural Gas terminal near the crude oil terminal in Le Havre-Antifer, and iii) the necessity for new dump-sites for dredged materials. Consequently, the increasing monitoring efforts have yielded a significant amount of new data concerning the coastal and estuarine benthic communities of the eastern part of the Bay of Seine (Dancie *et al.*, 2010; Laurand *et al.*, 2010; Dancie, 2011; Lanshere *et al*., 2011). Researchers now have annual, or biannual, data for the area between Antifer and the Seine estuary since 2002. Depending on the year, there were between 48 and 97 stations, which were sampled with a Smith–McIntyre grab (0.10 m², about 10 cm depth), with three benthic macrofauna replicates being collected at each station.

For the Seine Estuary, it appears that one of the main consequences of the huge development projects established over the last two decades is the silting-up the shallow waters of the eastern Bay of Seine (Dauvin *et al*., 2007). In order to understand the mechanism of the silting-up phenomenon, the Seine-Aval COLMATAGE program has been running since 2007 for five years (2007-2011). To define a range of seasonal variations of the benthic macrofauna, two summer surveys were organized in 2008 and 2009 with 58 and 54 stations respectively (Alizier, 2011). These summer samples were collected using a Van Veen grab (0.10 m² about 10 cm depth) with five benthic macrofauna grab samples at each station.

For each sampling occasion mentioned above, an additional sample was collected for sediment analysis.

Results

In spite of the regular sampling of the benthic macrofauna in the eastern Bay of Seine since 1970s, we report here the first, and repeated captures of *A. atlanticus* specimens in the eastern part of the Bay of Seine since 2008, especially in Antifer crude oil terminal, as well as off Le Havre (Fig. 1). All *A. atlanticus* specimens (30) were collected between 7 and 25 m depth, mainly on mud and muddy-sand (23 out of 27 stations). The remaining four stations were characterized by sandy sediments (Table 1). The sediment's fine particle content (< 63 µm) ranged from 2 % to 99 %. Many of the related macrobenthic assemblages included tubicolous organisms such as the polychaetes *Terebellides stroemi* Sars, 1835 and *Lanice conchilega* Pallas, 1766, and the burrowing thalassinid decapod *Upogebia deltaura* Leach, 1815, which were likely to provide suitable habitat for *A. atlanticus* (Glémarec & Hily, 1979).

The size of our specimens ranged from a carapace width of 2.2 mm to 10.0 mm. Most of them (24 individuals, 80%), including the non-measured specimens (Dancie, pers. com.) were relatively small sized, ranging between a carapace width of 2.2 mm and 4.8 mm (Table 1), and were sexually undeterminable . The remaining six individuals, ranging between 5.6 and 10.0 mm, were one male and five females. According to Bocquet (1965), the male and two females were young specimens in their fourth crab stage of development, while three females were adult specimens. None of these adult females was gravid.

Discussion

Recently, a collection of *Asthenognathus gallardoi* Serène & Soh, 1976, from Thailand and the Philippines has been examined by Naruse & Clark (2009). These authors proposed to create a new genus for this species: *Gopkittisak*. They also highlighted the need to provide a revision for the Atlantic *Asthenognathus*-like species, and underlined the difficulties for

classifying this small group of crustacean decapods. Given the taxonomic status of this complicated family, we propose to follow the European Register of Marine Species status of *A. atlanticus* (Costello *et al.*, 2008) for the specimens collected in the eastern Bay of Seine. This species is highly distinctive, and thus is unlikely to be overlooked or misidentified. As such, we can confirmed that no individual of *A. atlanticus* was ever collected in the eastern French part of the English Channel before the year 2008.

The records of *A. atlanticus* in the eastern part of the English Channel show a large distance between the known population which occurred in northern Brittany, and the new location of this species in the Bay of Seine. There is additional evidence that warm water species such as *A. atlanticus* are now able to extend their ranges into areas where the climate conditions, especially in winter, are milder than in the past (Mieszkowska *et al.*, 2006). Some species have extended their limits more than 160 km towards northern and eastern regions in the Channel (Williams, 2007). At least one other brachyuran species, *Pachygrapsus marmoratus* Fabricius, 1787, was known to move eastwards along the English Channel (Ingle & Clark, 2006; Dauvin, 2008). Ingle and Clark (2006) argued that the occurrence of *P. marmoratus* in the southern coastal waters of the British Isles is due to climate change which has induced favorable conditions for temporarily and sporadic introductions of more southern species from time to time. Thus, in the context of global warming, occasional fluctuations of the environmental factors or short-term climate cycles might have also played a preponderant role in the considerable fluctuations of the extreme northern and eastern limits of species (Southward & Southward, 1977).

In addition, *A. atlanticus* is known to live in various types of sediment, from muddy fine sand to mud and from the intertidal zone up to a depth of 210 m (Glémarec & Hily, 1979; Udekem d'Acoz, 1999). The sediment with fine particles content (< 50 µm) greater than 25% corresponds to the optimal habitat for this species around the Brittany (Bocquet, 1963;

Glémarec & Hily, 1979). In 2002, the tubicolous ampharetid, *Melinna palmata* Grube, 1870, was recorded for the first time in the muddy fine sand with *Abra alba – Pectinaria koreni* community of the eastern part of the Bay of Seine (Dauvin *et al*., 2007). This species' occurrence, and the consecutive growth of its population reflect the increase in fine particles in this part of the eastern Bay of Seine reported between 2001 and 2011 (Lesourd *et al*., 2001, 2003; Dauvin *et al*., 2007, unpublished data). The new records of *A. atlanticus* may then reflect the increase in subtidal mud habitats in the eastern Bay of Seine, due as much to human disturbances, as to climatic changes.

Since favorable environmental conditions, which allow this species to survive, seem to be established, the species' presence still raises the question on the possible causes of its introduction. Either natural or anthropogenic introductions vectors may be involved (Southward & Southward, 1977; Gollasch, 2002). Since crustacean larvae can move over large distances, natural migrations could occur via larval dispersal by residual currents. For example, Southward & Southward (1977) have already observed the arrival in Cornwall of the hermit crab *Clibanarius erythropus* Latreille, 1818, from 1955 to 1962 from South Brittany. Experiments conducted in controlled conditions at Roscoff (Brittany, France) by Bocquet (1965) showed that the *A. atlanticus* larval stage lasted about 45 days (6 weeks). Thus, covering the distance between Roscoff and the eastern Bay of Seine (≈ 325 km) over 45 days requires residual currents of ≈ 8 cm s^{-1}, which are well above the tidal residual currents of ≈ 3 cm s^{-1} reported in most parts of the English Channel (Salomon & Breton, 1993). Only an unusually favorable sequence of moderate and strong western winds over 6 weeks could have significantly increased residual currents to encourage such a transport. Although the distance between Saint Malo and the eastern Bay of Seine is shorter (≈ 250 km), the presence of mesoscale eddies in the Saint Malo gulf may increase residence times and limit larval export (Salomon & Breton, 1993; Lefebvre *et al.*, 2003).

Furthermore, the colonization of the eastern Bay of Seine following larval transport of *A. atlanticus* by residual currents, from the western to the eastern English Channel, implied that enough quantities of larvae were released, and survived in the planktonic stages for 6 weeks. However, as noted earlier, this species remains rare in the Western Channel. Conversely, such colonization seems likely if we assume that transitional populations of *A. atlanticus* are present in the Channel Islands, along the western and northern Cotentin coasts, as well as in the western Bay of Seine, as in the case of *Melinna palmata*. Thus, *Melinna palmata* was observed in the Cherbourg harbor where the favorable muddy sediment exists, which is likely to host *A. atlanticus* population (Dauvin *et al.*, 2007). However, we have yet to find any other report of the species from these areas, despite the many surveys carried out over the last thirty years (e.g. scientific monitoring programs, benthic environmental surveys, Water Framework Directory controls).

On the other hand, human intervention has frequently been involved in the introduction of non-native species, especially due to aquaculture practices and transportation by ship (Gollasch, 2002). The role of shellfish farming for *A. atlanticus* can be rejected because there is no activity occuring around Antifer. In contrast, Le Havre-Antifer harbor is an important crude oil terminal, designed to accommodate 550,000dwt super-tankers (http://www.havre-port.fr; 04/23/2010). Gollasch (2002) has shown that several brachyuran decapods species are found to travel by ship in tank sediments, hull fouling and ballast waters. Actually, many cases of ship-mediated introduction of non-native crab species such as *Eriocheir sinensis* Milne Edwards, 1853, *Hemigrapsus sanguineus* de Haan, 1835, *Hemigrapsus takanoi* Asakura and Watanabe, 2005, *Pachygrapsus. marmoratus* Fabricius, 1787 and *Rhitropanopeus harissii* Gould, 1841 have already been described in the English Channel and the North Sea (Vincent & Breton 1999; Breton *et al.*, 2002; Vincent & Noël, 2002; Breton, 2005; Ingle & Clark, 2006; Dauvin *et al.*, 2009). In addition, the fact that the

reports of *A. atlanticus* in the eastern part of the Bay of Seine came in the vicinity of large harbors (Antifer and Le Havre) leads us to consider that ship-mediated introduction as the most likely hypothesis.

We are unable to assert that individuals of *A. atlanticus* collected in the eastern part of the Bay of Seine since December 2008 belong to a self-sustaining population. Until now, there is no evidence of reproduction in the wild. The adults observed are very few in numbers and even then their presence does not necessarily mean that a self-sustaining population is established (Southward & Southward, 1988).

Conclusion

The presence of *Asthenognathus atlanticus* in the eastern part of the Bay of Seine has been reported for four consecutive years, from 2008 to 2011. There is no evidence that the specimens collected are part of a self-sustaining population, even if the recent changes in local environment lead to favorable conditions for this species. Since i) there has been no report of this species' presence between Saint Malo and Antifer, and ii) the several observations have come in the vicinity of important harbors, and thus, at this point in time, the most likely hypothesis of these recent observations would be ship-mediated introductions. Further explorations or existing monitoring programs will need to pay particular attention to this species in order to define its spatial distribution precisely, and to determine if it will develop into a self-sustaining population. Population genetic analyses, processed on alcohol-preserved specimens that could be sampled directly in the field, would thus be useful to i) understand the introduction history of this species in the eastern Bay of Seine and ii) to re-examine the taxonomic status of this species which seems to be unclear.

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Table 1: Main characteristics of the sampling location where *Asthenognathus atlanticus* individuals were collected from 2008 to 2011 (Coordinates WGS84; ND: no data).

Tableau 1 : Principales caractéristiques des stations où *Asthenognathus atlanticus* a été échantillonné entre 2008 et 2011 (coordonnées WGS84 ; ND : absence de donnée).

Date	Campaign	X	Y	Ni	Sediment (Folk diagram)	Width (mm)
16/12/08	OCTEVILLE	0°01.00'E	49°38.00'N	2	Sandy mud	2.8 ; 3.2
27/08/09	COLMATAGE	0°01.14'W	49°31.62'N	1	Muddy sand	10.0
01/09/09	COLMATAGE	0°09.30W	49°18.82'N	1	Muddy sand	9.8
23/09/09	ANTIFER	0°08.50'E	49°39.81'N	1	Sandy mud	6.6
23/09/09	ANTIFER	0°08.54'E	49°39.61'N	1	Muddy sand	3.4
23/09/09	ANTIFER	0°08.78'E	49°39.31'N	1	Sandy mud	5.6
23/09/09	ANTIFER	0°08.67'E	49°39.73'N	1	Sandy mud	2.4
23/09/09	ANTIFER	0°07.98'E	49°39.35'N	1	Sandy mud	2.2
23/09/09	ANTIFER	0°07.75'E	49°39.02'N	1	Sandy mud	3.1
24/09/09	ANTIFER	0°08.84'E	49°39.45'N	1	Sandy mud	2.6
24/09/09	ANTIFER	0°07.15'E	49°39.14'N	1	Sandy mud	7.5
24/09/09	ANTIFER	0°05.94'E	49°39.39'N	1	Sand	2.2
24/09/09	ANTIFER	0°06.80'E	49°38.78'N	1	Sandy mud	3.2
15/12/09	OCTEVILLE	0°01.00'E	49°35.00'N	1	Muddy sand	3.9
15/12/09	OCTEVILLE	0°02.00'E	49°35.00'N	1	Sandy mud	4.8
15/12/09	OCTEVILLE	0°06.00'E	49°38.00'N	1	Muddy sand	4.8
15/12/09	OCTEVILLE	0°00.28'W	49°31.88'N	1	Sandy mud	3.7
21/04/10	ESTUAIRE	0°02.60'E	49°25.13'N	1	Sandy mud	ND
19/11/10	OCTEVILLE	0°04.00'E	49°35.00'N	1	Sandy mud	ND
19/11/10	OCTEVILLE	0°00.23'W	49°30.90'N	2	Muddy sand	ND
19/11/10	OCTEVILLE	0°00.28'W	49°31.88'N	2	Muddy sand	ND
19/11/10	OCTEVILLE	0°02.00'E	49°35.00'N	1	Sandy mud	ND
03/12/10	OCTEVILLE	0°05.00'E	49°38.00'N	1	Sand	ND
03/12/10	OCTEVILLE	0°06.00'E	49°38.00'N	1	Muddy sand	ND
21/12/10	CNEXO	0°06.40'W	49°30.80'N	1	Sand	ND
21/12/10	CNEXO	0°06.56'W	49°31.15'N	1	Sand	ND
13/03/11	PECTOW	0°07.88'E	49°39.63'N	1	Muddy sand	9.0

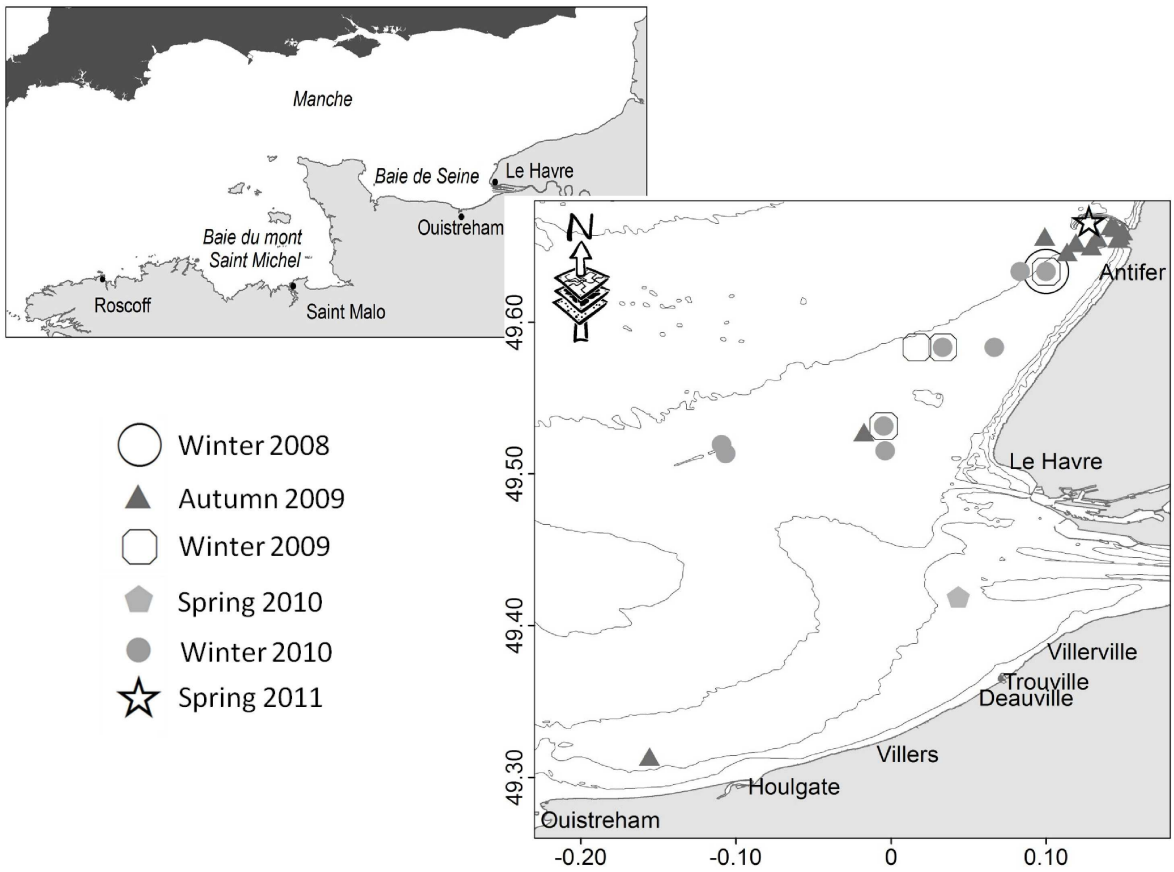

Figure 1: Map of the sampling stations where *Asthenognathus atlanticus* was collected in the Eastern part of the Bay of Seine.

Figure 1 : Carte des stations de la partie orientale de la baie de Seine au niveau desquelles *Asthenognathus atlanticus* a été échantillonné.